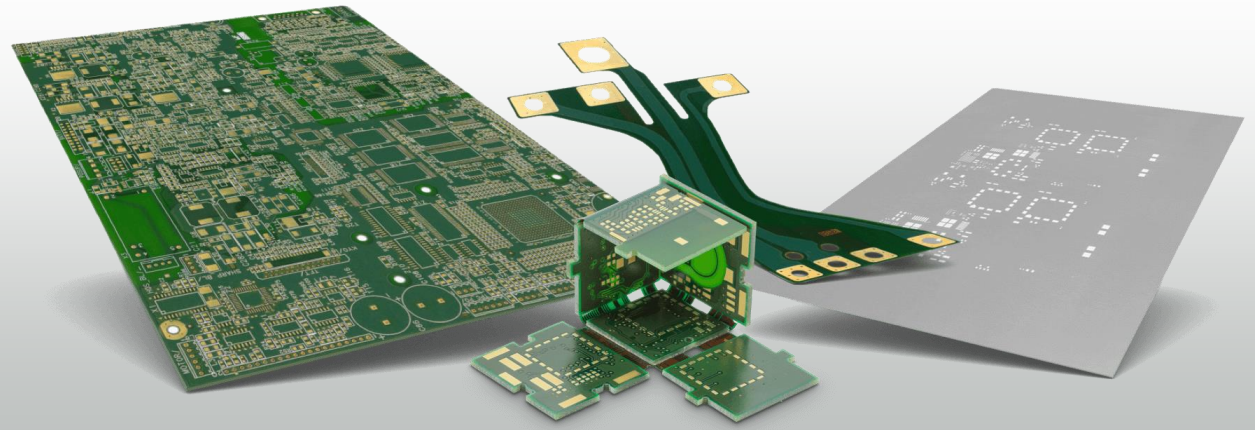
WÜRTH ELEKTRONIK

How does your PCB layout influence the costs in PCB manufacturing?



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How does your PCB layout influence the costs in PCB manufacturing?

Agenda

- PCB array
- Copper price development and choice of materials
- PCB stackup
- Mechanical processing
- Advanced technologies
- More tips & tricks
- Summary

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How does your PCB layout influence the costs in PCB manufacturing?

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- **PCB array**
- Copper price development and choice of materials
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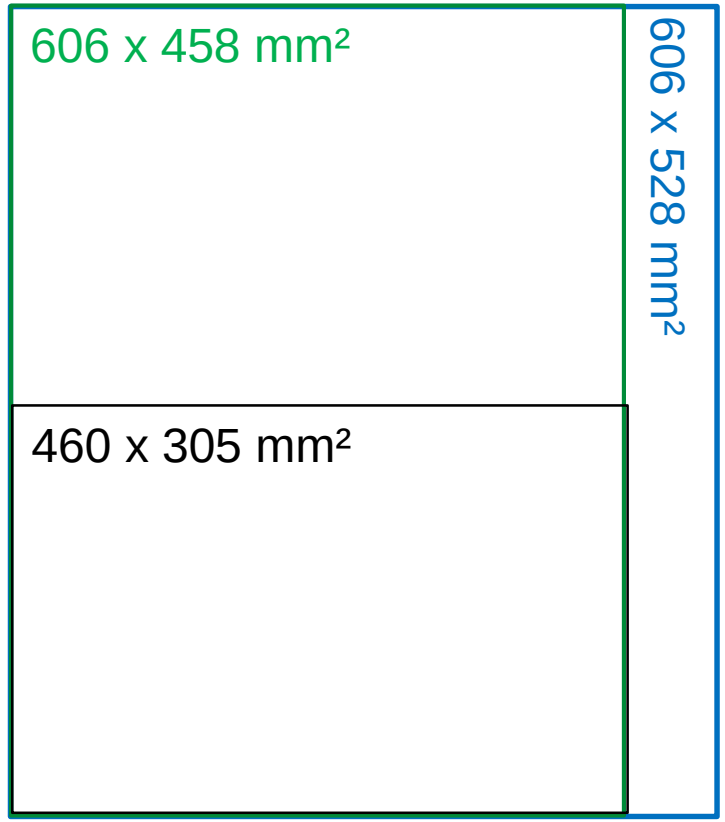
The PCB array

How to utilize and occupy the manufacturing panel properly?

The Key Factor: How is the manufacturing panel occupied with PCBs?

- **Background information:**
  - PCB materials are manufactured in large panels
    90% of EU and US manufacturers of FR4 uses these formats:
    - US-Format: 1.225 x 925 mm²
    - Uni-Format: 1.225 x 1.070 mm²
  - 95% of PCB manufacturers in EU & US
    use these panel formats:
    - 460 x 305 mm² (1/8 US-Format) WE sample format
    - 606 x 458 mm² (1/4 US-Format) WE standard format
    - 606 x 528 mm² (1/4 Uni-Format) WE jumbo format



The PCB array

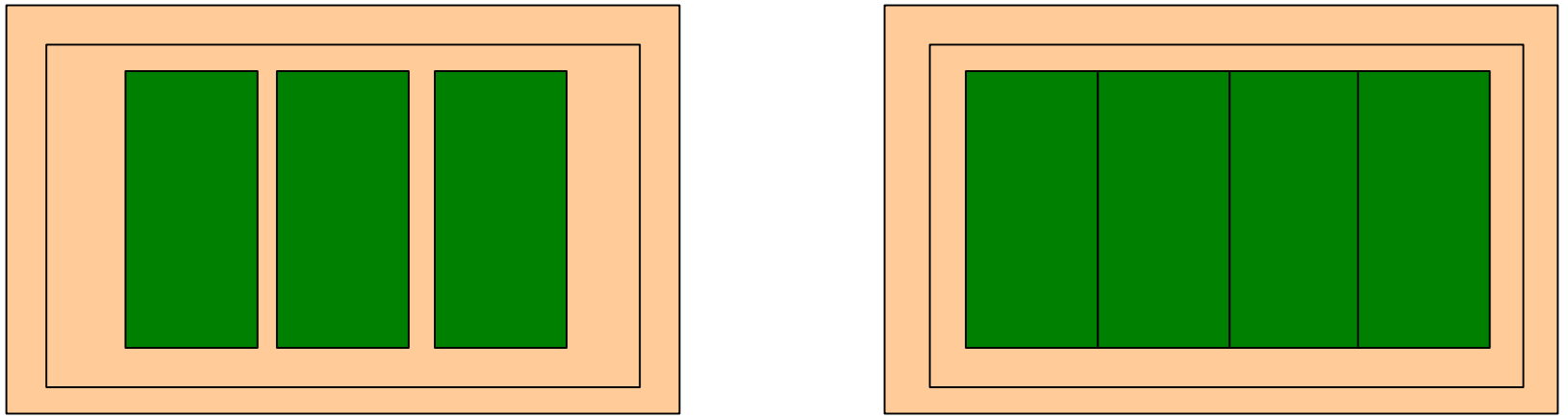
How to utilize and occupy the manufacturing panel properly?

The Key Factor: How is the manufacturing panel occupied with PCBs?

- **Every PCB manufacturer needs a border for registration and labeling ⇨ Non-useable space!**

Example: Single PCBs

Routing **oder** **V-Scoring**



In this example: 33% more circuit boards on the production panel

The PCB array

How to utilize and occupy the manufacturing panel properly?

The Key Factor: How is the manufacturing panel occupied with PCBs?

- **Every PCB manufacturer needs a border for registration and labeling ⇨ Non-useable space!**

Example: Single PCBs – The smaller the PCB, the greater the effect!

Routing **or** **V-Scoring**

In this example: 56 PCBs vs. 85 PCBs

The PCB array

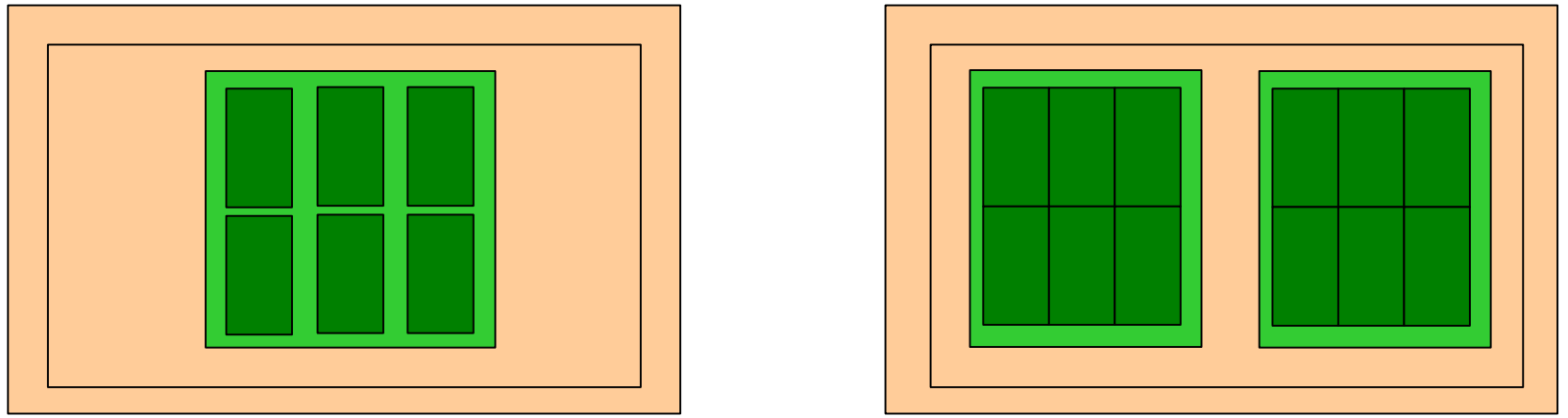
How to utilize and occupy the manufacturing panel properly?

The Key Factor: How is the manufacturing panel occupied with PCBs?

- **Every PCB manufacturer needs a border for registration and labeling ⇨ Non-useable space!**

Example: PCBs in array

Routing **or** **V-Scoring**

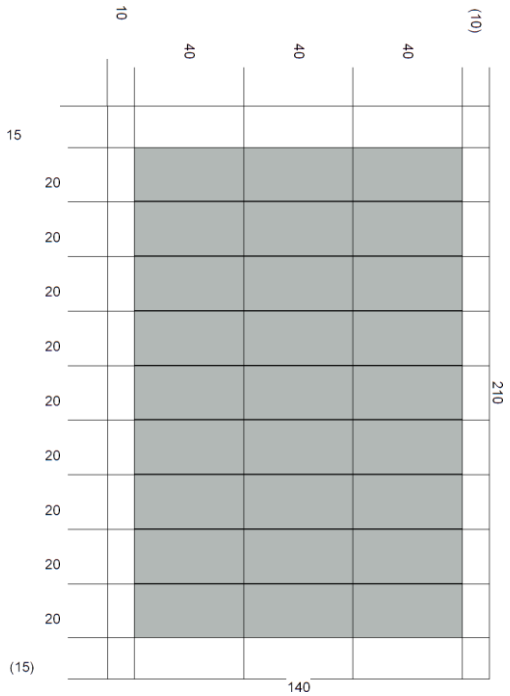


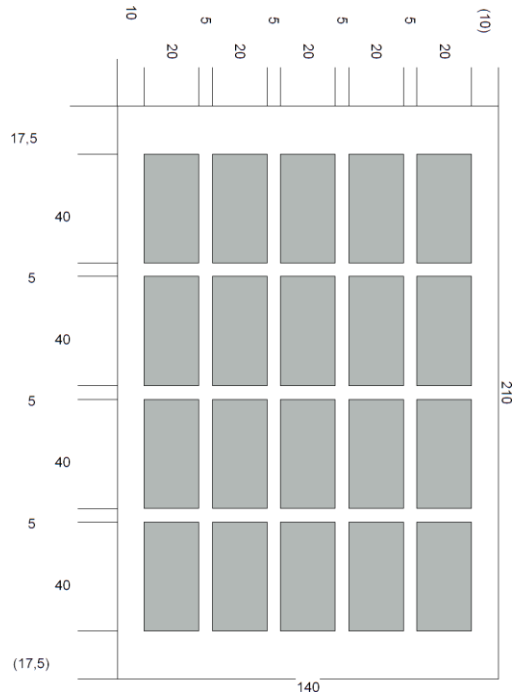
In this example: 100% more circuit boards on the production panel

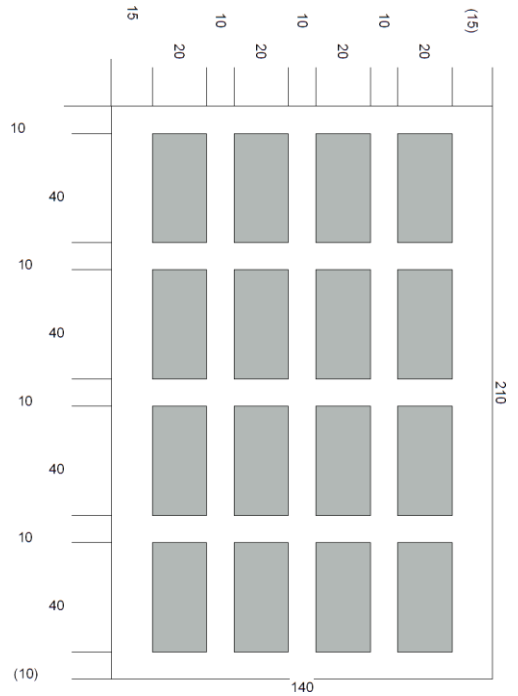
The PCB array

How to utilize and occupy the manufacturing panel properly?

- **Calculation Basis:**
  - ML6 / Base Material T_g150
  - PCB size 20 x 40 mm²
  - Array size 210 x 140 mm²
  - 100 µm L/S
  - 500 drills
  - 0,20 mm smallest drill-Ø
  - ENIG







PCBs on a production panel	**216**	**160**	**128**
Number of production panels (1.000 PCBs ordered)	5	7	8
PCBs in an array	27	20	16
PCB outline	**V-scored**	**routed**	**routed**
PCB distance in array	0,00 mm	5,00 mm	10,00 mm
Price indicator	**100%**	**117%**	**131%**

The PCB array

How to utilize and occupy the manufacturing panel properly?

The Key Factor: How is the manufacturing panel occupied with PCBs?

WE-Format		Sample format	Standard format	Jumbo format
Technologies		All technologies	Basic, flex-rigid & HDI	Basic & HDI
Plant		Rot am See	Niedernhall	Schopfheim
			Used in Schopfheim for special constructions	Niedernhall on demand
Panel size		460 x 305 mm²	606 x 458 mm²	606 x 528 mm²
Usable area		426 x 271 mm²	572 x 424 mm²	570 x 500 mm²
	Number of arrays	dimensions array		
Best array	1	426 x 271 mm²	572 x 424 mm²	570 x 500 mm²
for	2	271 x 213 mm²	424 x 286 mm²	500 x 285 mm²
V-scored outlines	4	213 x 135 mm²	286 x 212 mm²	285 x 250 mm²
	6	142 x 135 mm²	212 x 190 mm²	250 x 190 mm²
	8	135 x 106 mm²	212 x 143 mm²	250 x 142 mm²
	9	142 x 90 mm²	190 x 141 mm²	190 x 166 mm²
	12	106 x 90 mm²	143 x 141 mm²	166 x 142 mm²
	15	90 x 85 mm²	141 x 114 mm²	166 x 114 mm²

Tips:

- Edge of array edge min. 5 mm
- Edge of array 8 - 10 mm for routed outlines
- 2 edges with 5 - 10 mm for V-scored outlines
- Size of array should be based on thickness of PCB (the thinner the smaller)

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Copper price development and choice of materials

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Summary

Development of copper prize

Role of material price in PCB price

Copper price:

- **Developments on the London commodity exchange**

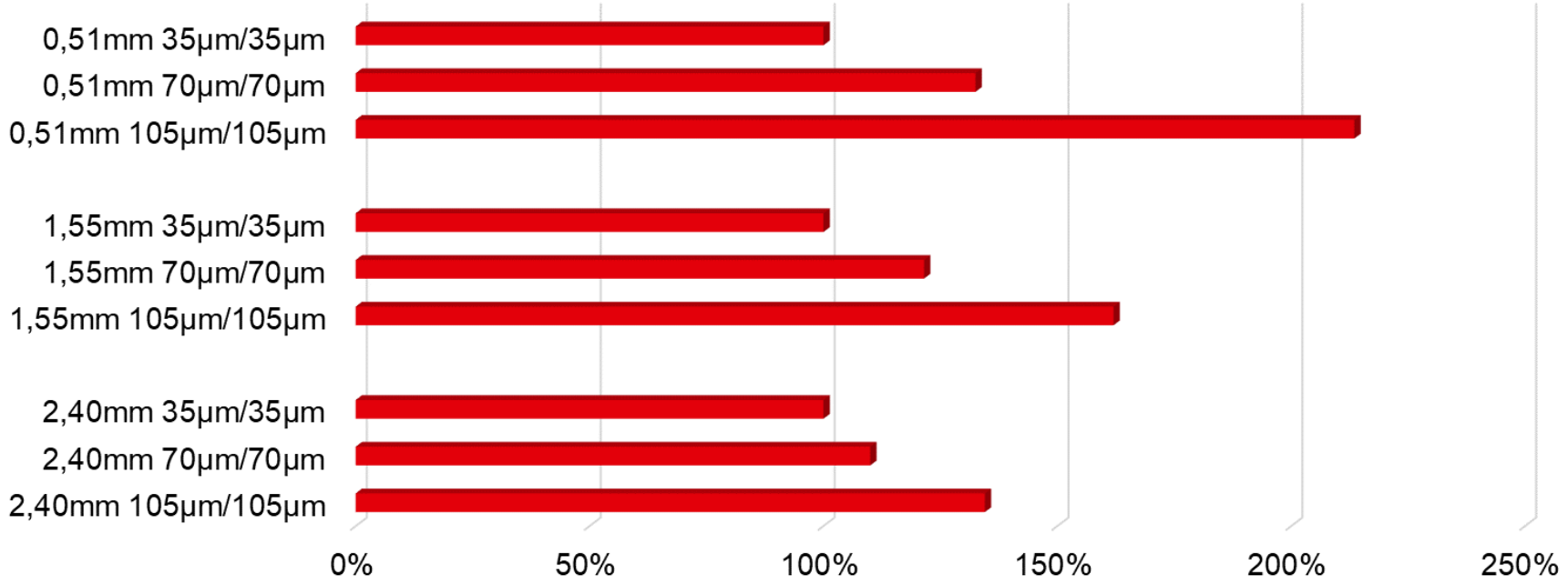
Time period: Jan. 2016 until June 2020

Source: http://www.boerse.de – data downloaded on 22.06.2020

Development of copper prize

Role of material price in PCB price

Comparison of material purchasing prices for FR4 T_g150 (as of July 2020)



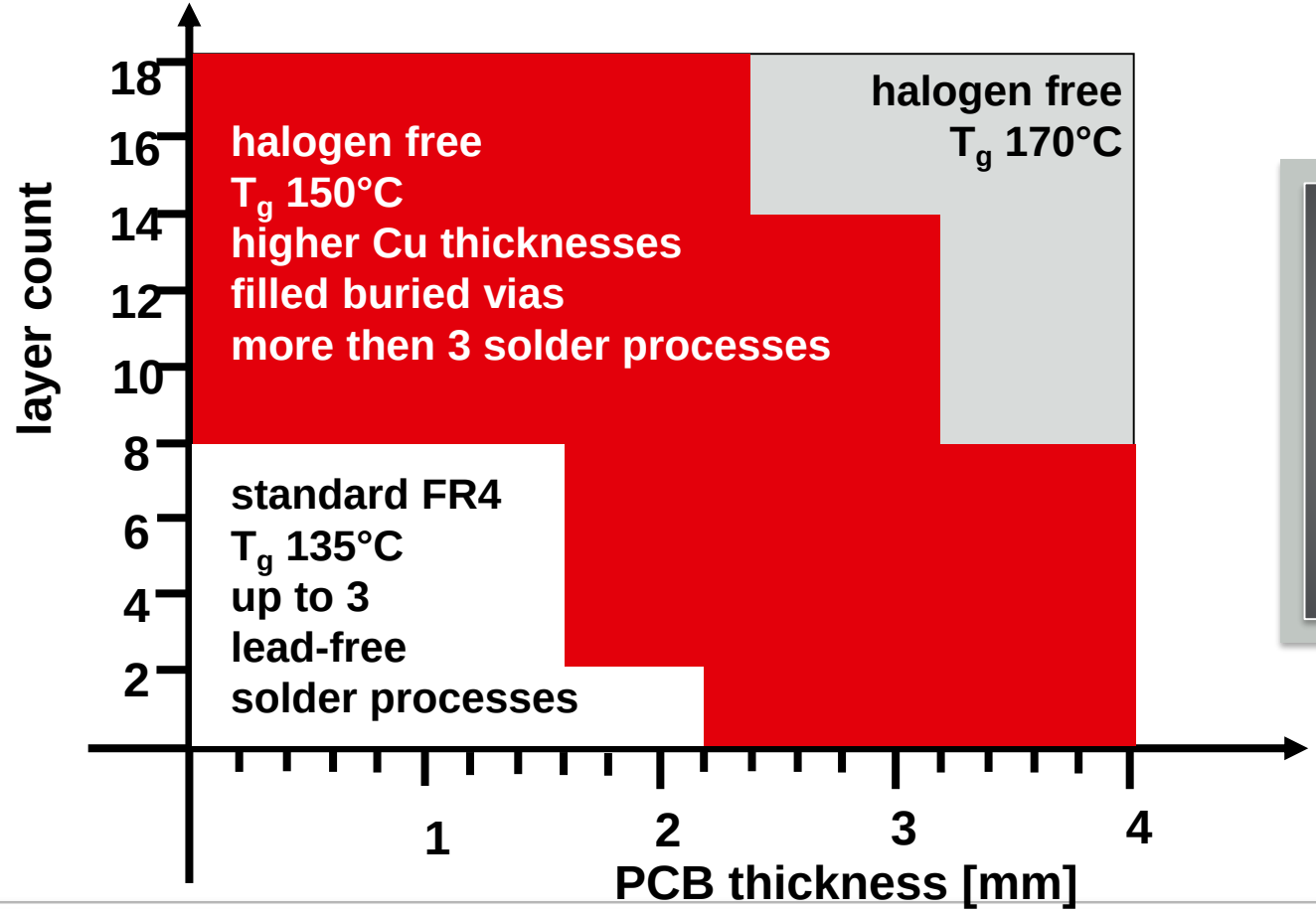
Copper plays an important role in the price of PCBs!

Hence the question: What is necessary or what is possible?

Choice of material

When to use which base material?

- **A small recommendation for the usage of base materials at Würth Elektronik**



Example comparison:
1,6mm / 6 layers
Multilayer
price increase
T_g135 to T_g150: 23%

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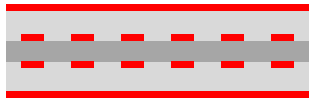
Layer stackup

How does the PCB construction influence the price?

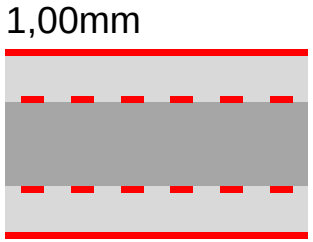
- **Comparison of a 4-layer multilayer with different thicknesses**
  - Standard: 1,55 mm / 1,60 mm
  - Optimum: 1,00 mm
  - Further standards:
    0,80mm / 2,00 mm / 2,40 mm



ML4_TG150_0.50_35

1x 0.10mm-035+035
4x prepreg 1080

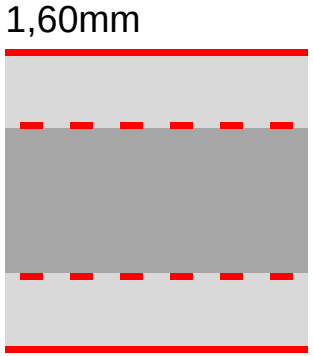
Price indicator 107%



ML4_TG150_1.00_35

1x 0.41mm-035+035
4x prepreg 2116

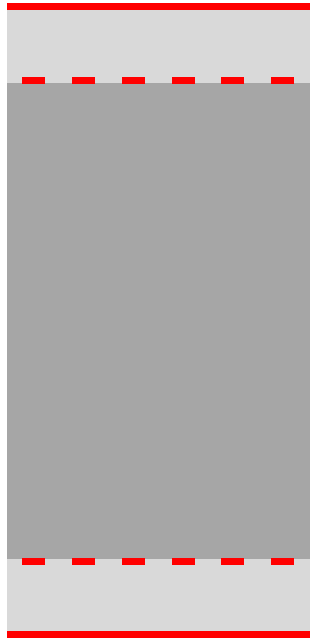
Price indicator 96%



ML4_TG150_1.60_35

1x 0.71mm-035+035
4x prepreg 7628

Price indicator 100%



ML4_TG150_3.20_35

1x 2.40mm-035+035
4x prepreg 7628

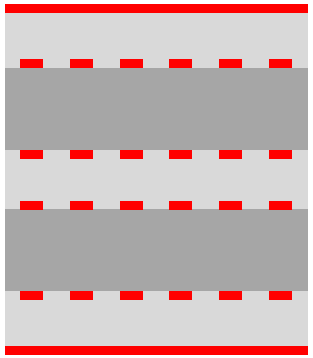
Price indicator 137%

Layer stackup

How does the PCB construction influence the price?

- **Comparison of a 6-layer multilayer: 1,60 mm standard vs. individual stackup**

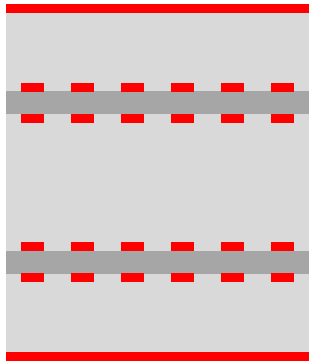
Standard stackup



2x 0.36mm-035+035
6x prepreg 2116

Price indicator 100%

Specific stackup



2x 0.10mm-035+035
2x prepreg 2116
8x prepreg 7628

Price indicator 116%

Additional costs:

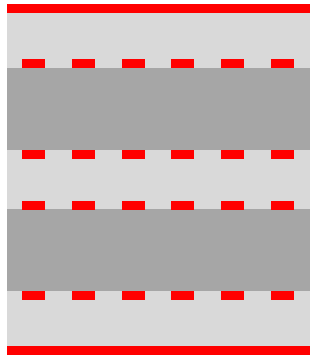
- **Handling thin laminate**
- **4 prepregs more in stackup**

Layer stackup

How does the PCB construction influence the price?

- **Comparison of a 6-layer multilayer: 1,60 mm standard vs. individual stackup**

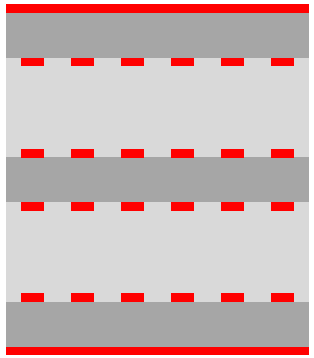
Standard stackup



2x 0.36mm-035+035
6x prepreg 2116

Price indicator 100%

Core-based stackup



3x 0.20mm-035+035
4x prepreg 2116
2x prepreg 7628

Price indicator 122%

Additional cost:

- **Multiple exposure of the outer layer cores (process quasi like an 8-layer PCB)**
- **More cores**

Further cost drivers

- **Filling cores in stackup**

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PCB array

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PCB stackup

Mechanical processing

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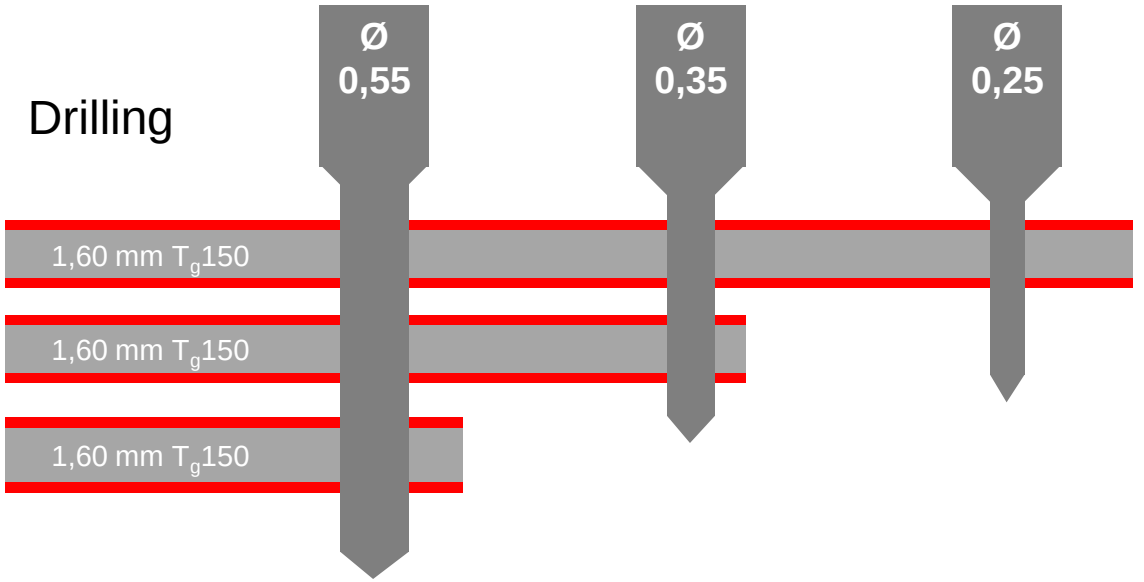
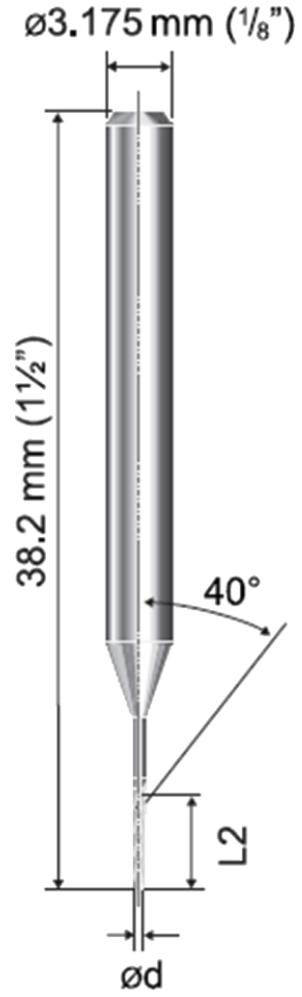
Summary

Mechanical processing

Which influence do the drilling tools have on the PCB costs?





Tool life Panel stacking	1.250 strokes stack of 3	1.000 strokes stack of 2	500 strokes stack of 1
Time to drill 15.000 vias	0,2 h	0,4 h	0,8 h
Usage of drill bits for 15.000 vias	4	7,5	30
Price indicator (only drilling process)	**100%**	**200%**	**460%**

Mechanical processing

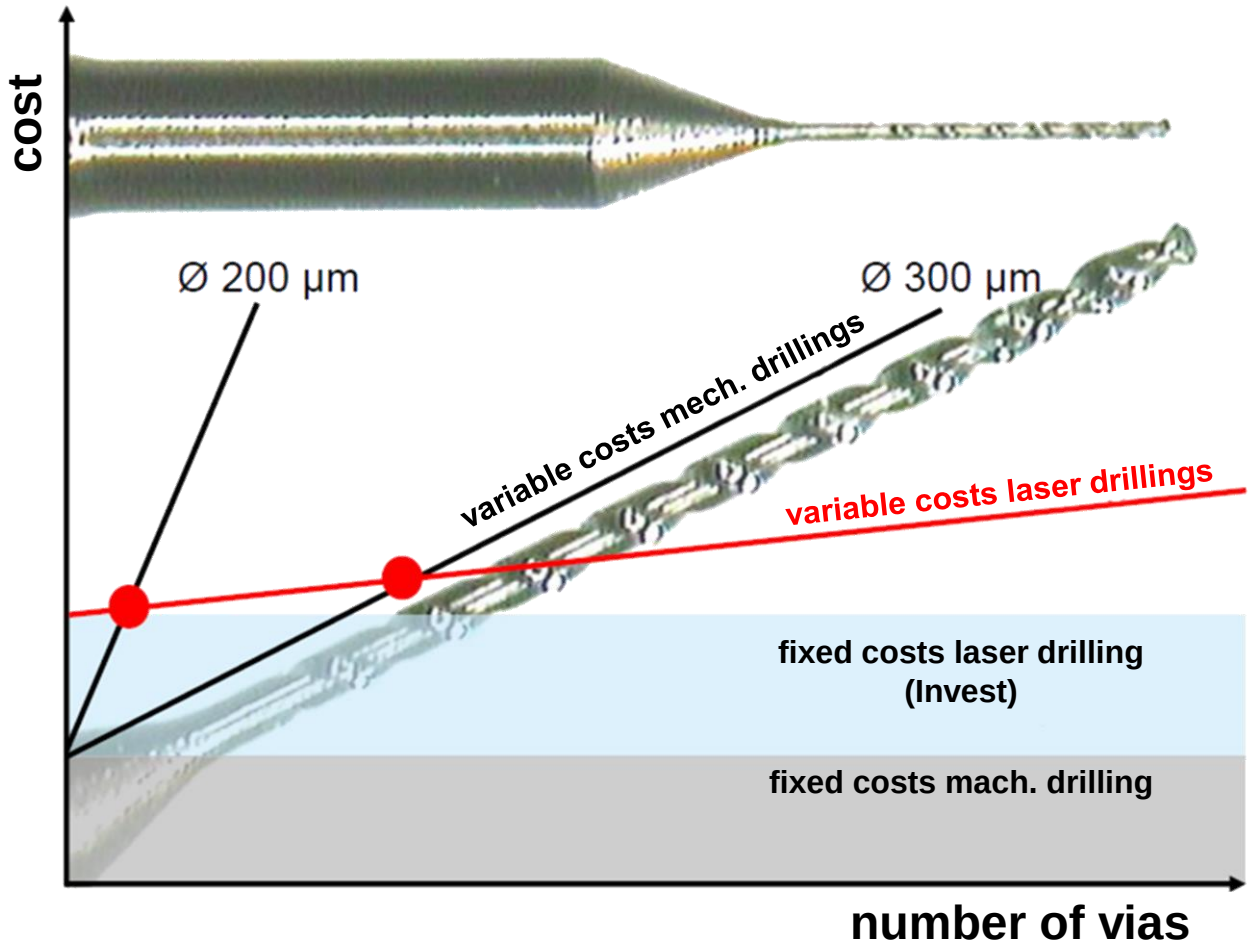
Which influence do the drilling tools have on the PCB costs?

- **Comparison:**

  Ø 0,5 mm, Ø 0,35 mm und Ø 0,25 mm drill bits on 5 mm x 5 mm checkered paper

Mechanical processing

Which influence do the drilling tools have on the PCB costs?



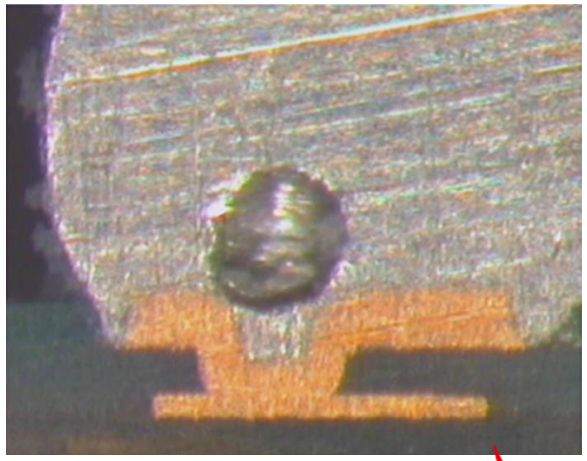
Ø 0,2 mm (0,55 € pro Bit)
Tool life: 750 strokes
Drilling frequency: 5 / s

Ø 0,3 mm (0,50 € pro Bit)
Tool life: 1.000 strokes
Drilling freq.: max. 8 / s

Microvia
Ø 0,125 mm
Drilling freq.: 150–180 / s

Mechanical processing

Filling of Microvias or not? That is the question!

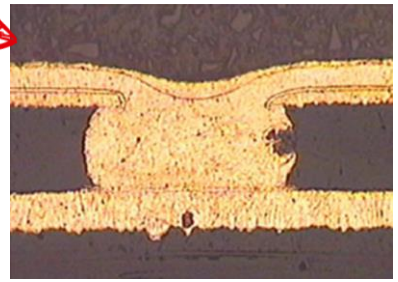


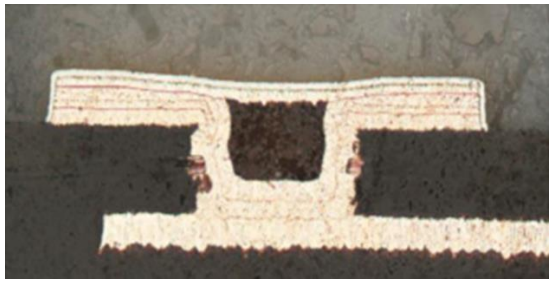
filling

IPC-7095C – Table A-3 – Class III: Max. „22% of the image diameter“

The formation of voids depends, among other things, on:

- **Flux / solder paste**
- **Temperature profile of the solder process**
- **Uniform heating or through-heating of the circuit board**





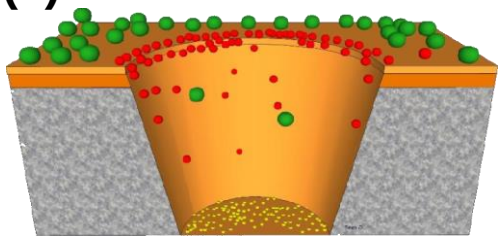
Every user has to define for himself how to manufacture!

Mechanical processing

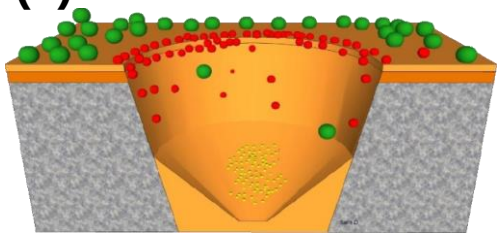
Filling of Microvias or not? That is the question!

Sequence Cu-Filling Process (Source/publication: MacDermidEnthone Electronic Solutions / 2018)

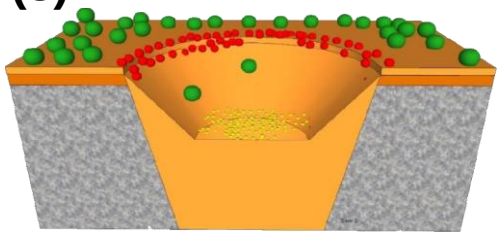
(1)



(2)



(3)



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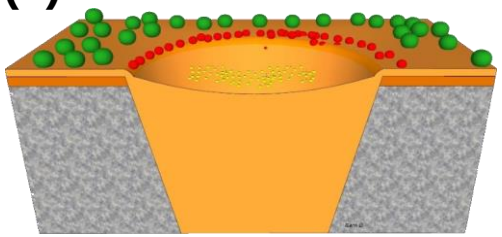
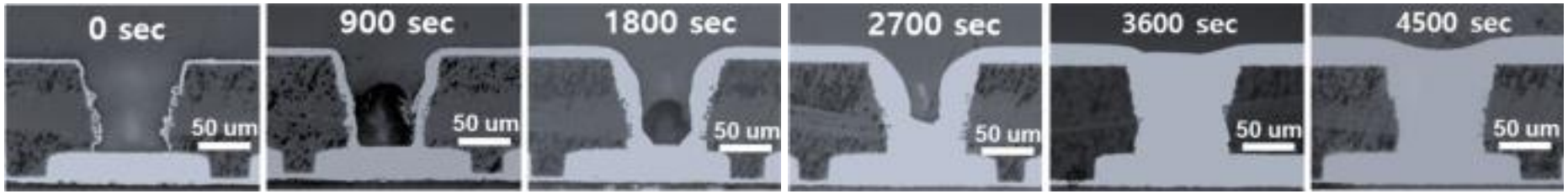


Legend:
- Wetter/Suppressor — Role: Molecules occupy the surface and block the deposition of Cu
- Leveler — Role: Molecules accumulate at the location of the highest current densitiy and block the deposition of Cu
- Brightener — Role: Brightener for the reduction of Cu crystal sizes

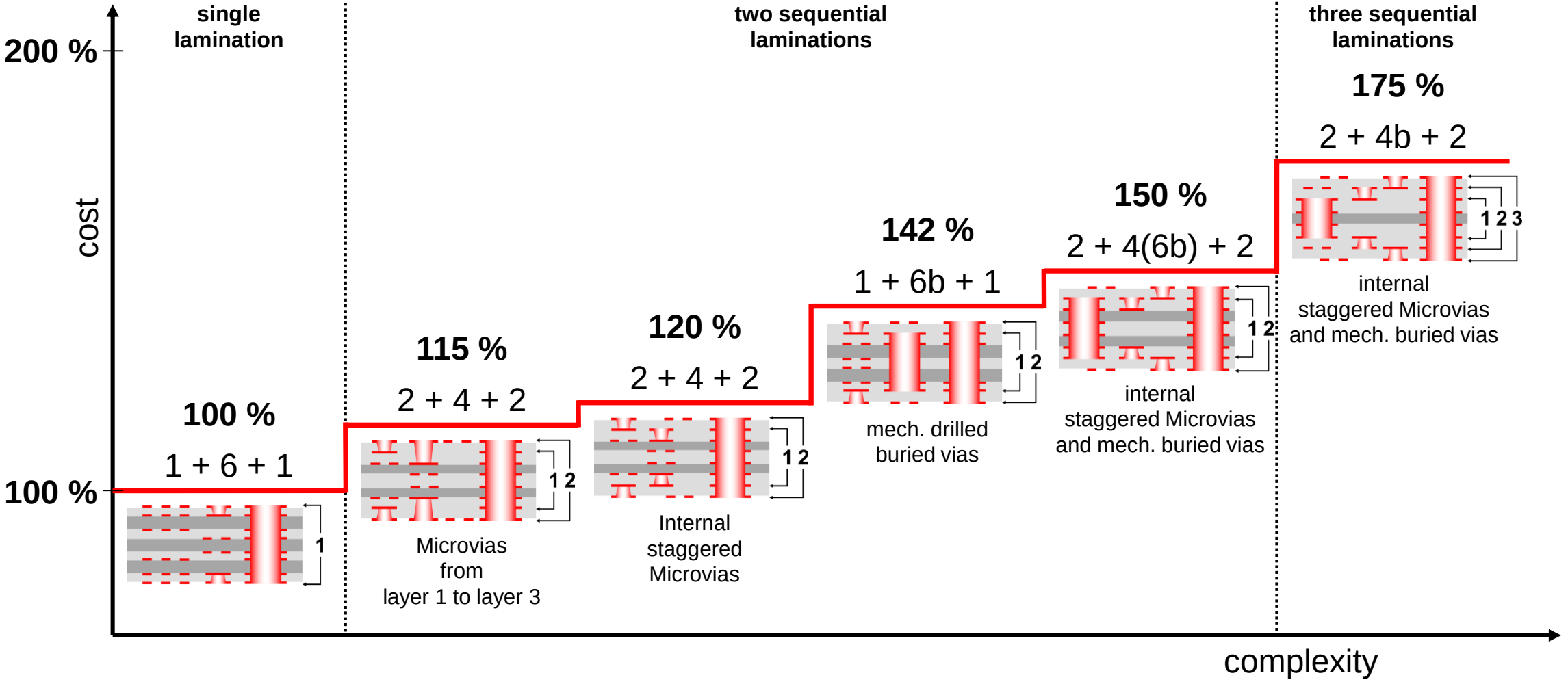
Time sequence (Source/publication : KAIST / 2019)



Process takes factor 2-3 longer compared to standard

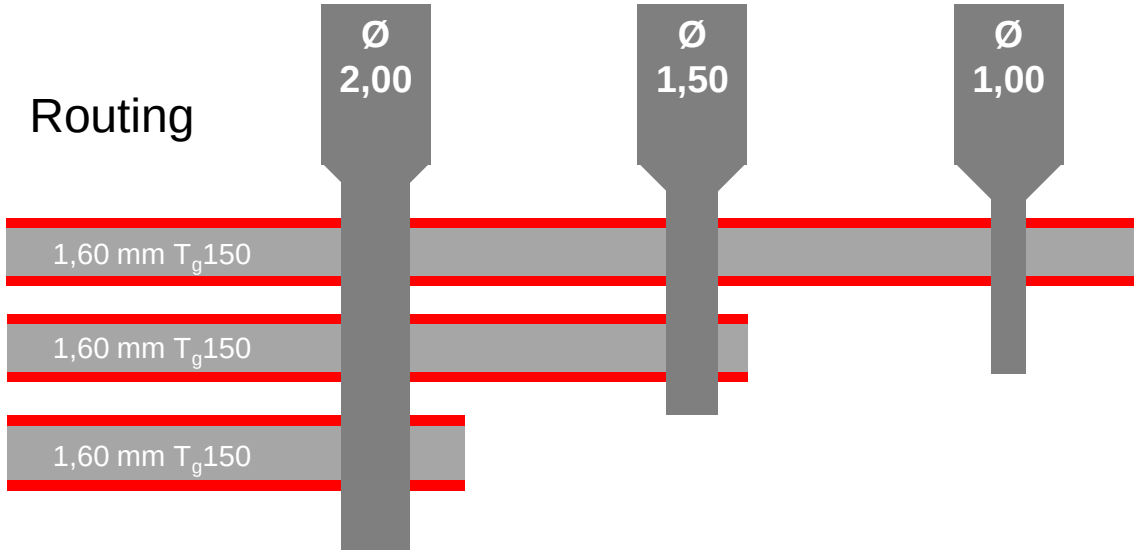
Mechanical processing

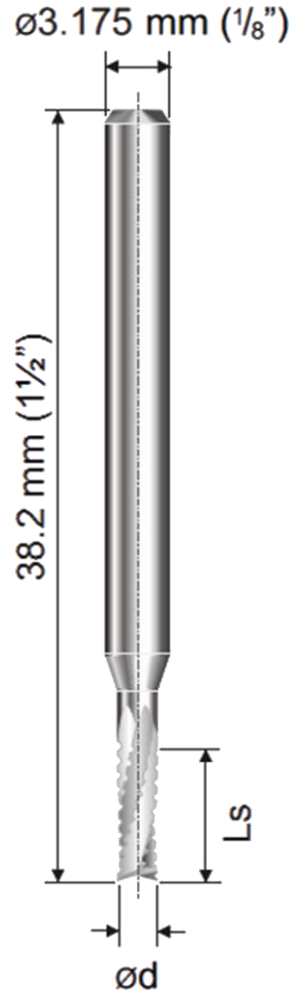
What influence does the HDI layer stackup have?



Mechanical processing

Which influence do the routing tools have on the PCB costs?





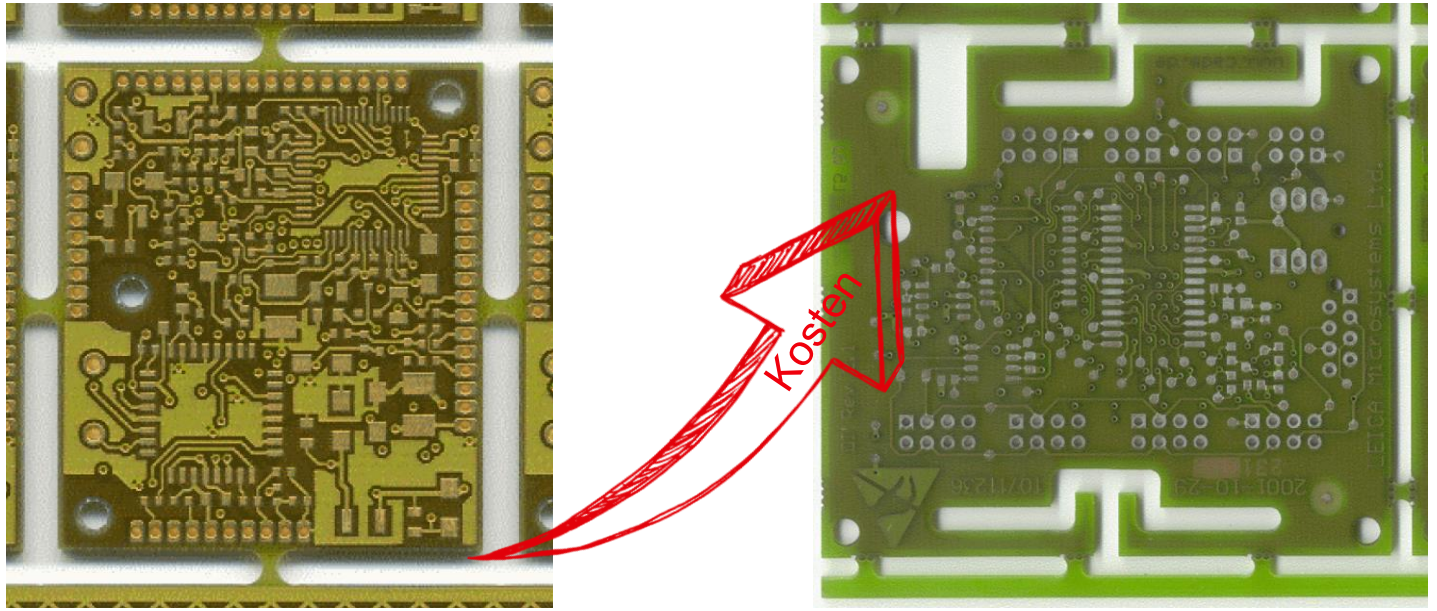
Tool life Panel stacking	15 m stack of 3	5 m stack of 2	3 m stack of 1
Tools for 100 PCBs with 0,5m routing path	1,1	5	16,7
Feed Time to route 100 PCBs with 0,5m routing path	1,2 m/min 0,2 h	0,7 m/min 0,6 h	0,3 m/min 2,8 h
Price indicator (only routing process)	**100%**	**270%**	**1200%**

Mechanical processing

What else has an influence on the price of PCBs?

- **Routing contour**

  Complex routing contours can lengthen the routing paths and have a negative influence on the routing tool diameter



Standard routing contour

- **4x change in direction**
- **routing tool 2,4 mm**

Complex routing contour

- **approx. 30x change in direct.**
- **high routing time**
- **routing tool 1,8 mm**

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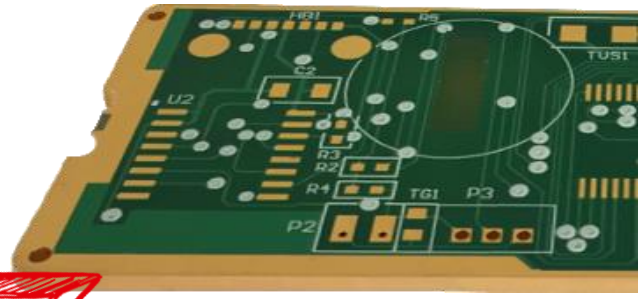
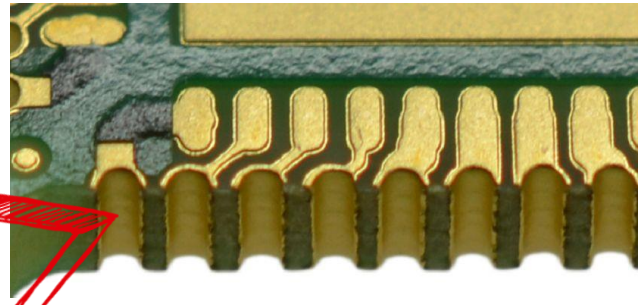
Advanced technologies

What else has an influence on the price of PCBs?

Further cost drivers!

- **PCB thickness / layer count**
  ⇨ not only relevant for drilling & routing….
- **Number of laminations**
- **Edge plating / side plating**
- **Castellated holes / Castellation**

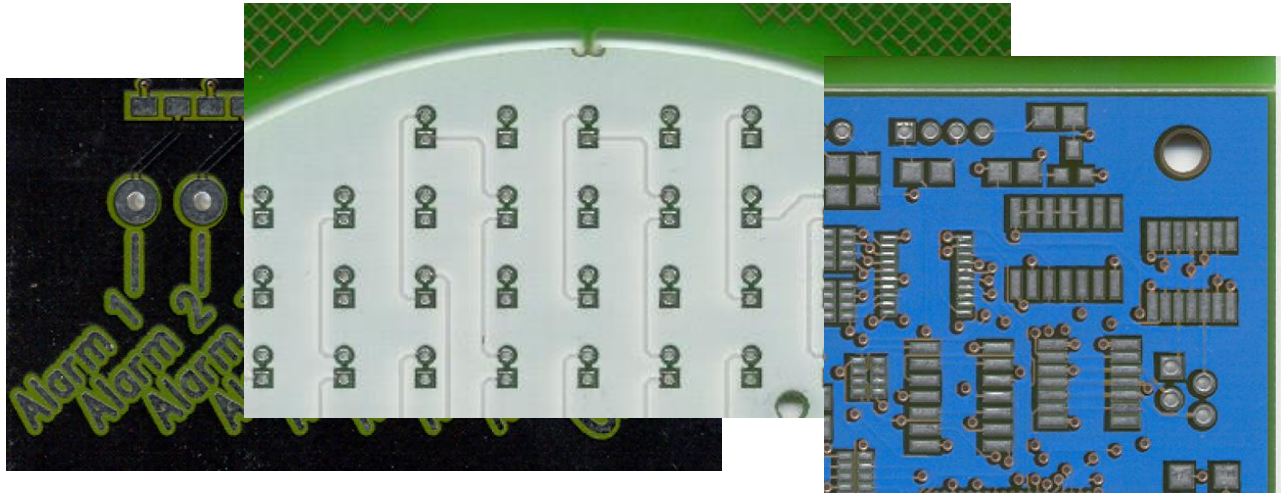




Advanced technologies

What else has an influence on the price of PCBs?

Further cost drivers!



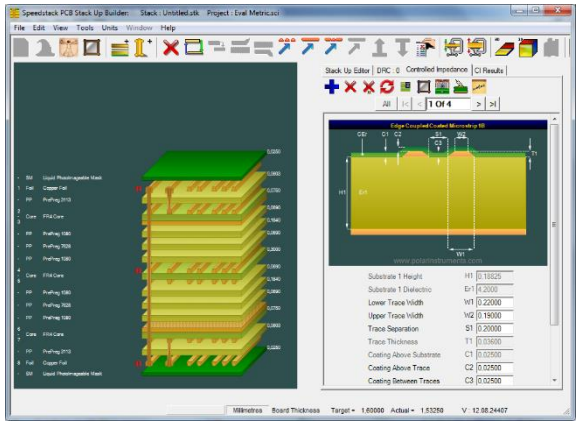
- **Colored solder resist**
  - White / black / red / blue
  - The problem: demand extremely low
  - Question: Does it always have to be solder resist - or is it sufficient to mark PCBs with a colored legend printing (e.g. additional red/yellow for prototypes / samples without series approval)

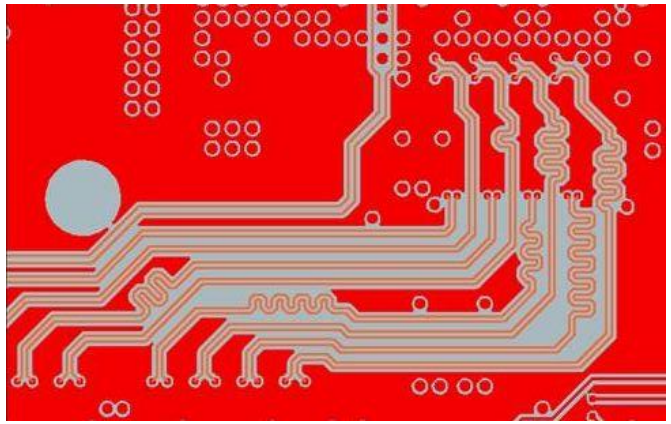
- **Legend printing**
  - How small must be printed? Danger: printing onto pads

Advanced technologies

What else has an influence on the price of PCBs?

Required or needed impedances





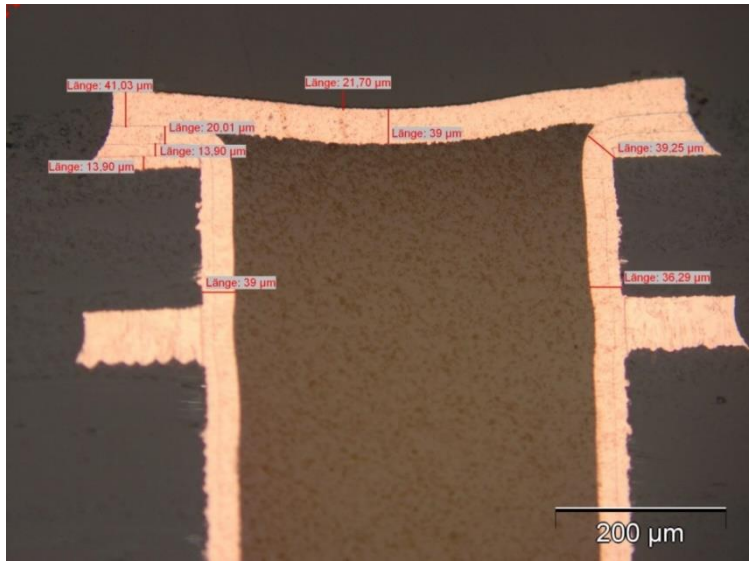
- **Impedance watching / controlled dielectric**
  ⇨ Calculated stackup and tracks, no TDR coupons

- **Impedance control**
  ⇨ additional TDR coupon (or coupons) on manufacturing panel
  ⇨ reduced number of PCBS on manufacturing panel

Advanced technologies

What else has an influence on the price of PCBs?

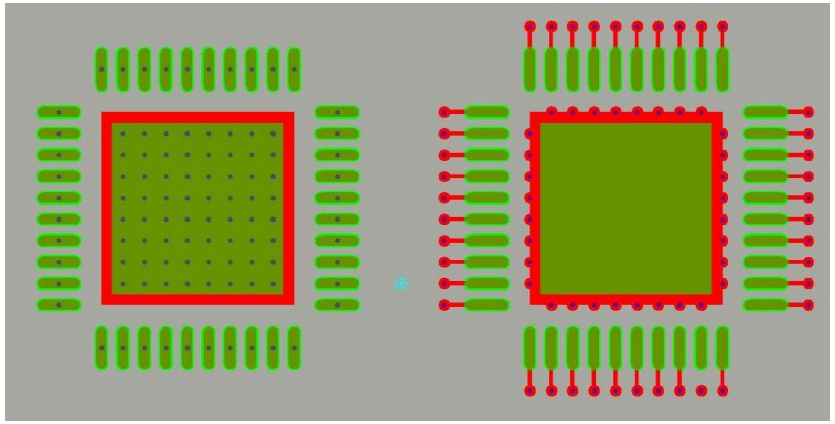
- **IPC 4761 – Filled and Capped Via (Type VII Via)**
  ⇨ Via filled with resin and plated with Cu



**Necessary or
to be avoid with
intelligent design?**

usage:

**e.g.
cooling areas
vias in solder pads
vacuum tightness**



Advanced technologies

What else has an influence on the price of PCBs?

- **Request: IPC Class 3**

  The requirement of 25µm copper in the barrel is often mistaken with the requirement of IPC Class 3 production:

  – 25µm barrel copper is only a part of the requirement of IPC Class 3

  – However, the stricter test criteria according to IPC Class 3 lead to a lower yield and, together with the effort to check the criteria, to an increased price!

Advanced technologies

What else has an influence on the price of PCBs?

- **Electroplated Gold**

Usage of electroplated Gold

- often used for contacts as an abrasion resistant surface
- mostly selective in combination with ENIG
- with thicknesses up to 4µm

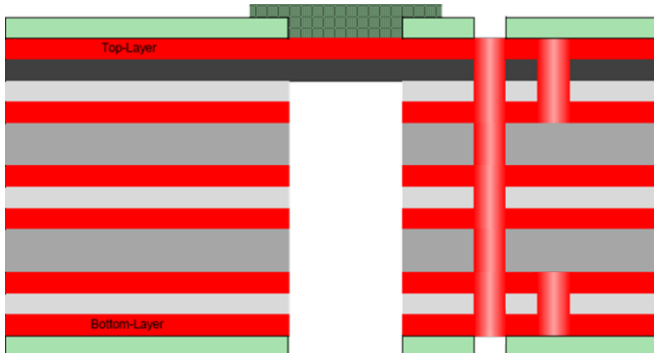
Price indicator: up to 500% or more (depends on the current price of gold)

Source: http://www.boerse.de – data downloaded on 13.07.2020

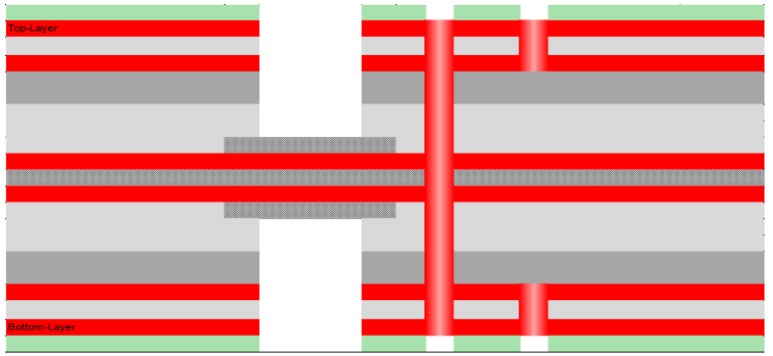
Advanced technologies

Who about flex-rigid stackups?

- **Flex-rigid 1F-5Ri / HDI 1-4-1**



- **Flex-rigid 2Ri-2F-2Ri / HDI 1-4-1**



- **Single sided vs. double sided effort for mechanical depth milling**
- **Huge price differences for the flex material: copper on one or both sides**
- **Screen-printed flexible solder resist is cheaper than routed and laminated coverlay**
- **For higher reliability with xRi-2F-xRi: Partial coverlay (Bikini coverlay) required**

How does your PCB layout influence the costs in PCB manufacturing?

Agenda

PCB array

Copper price development and choice of materials

PCB stackup

Mechanical processing

Advanced technologies

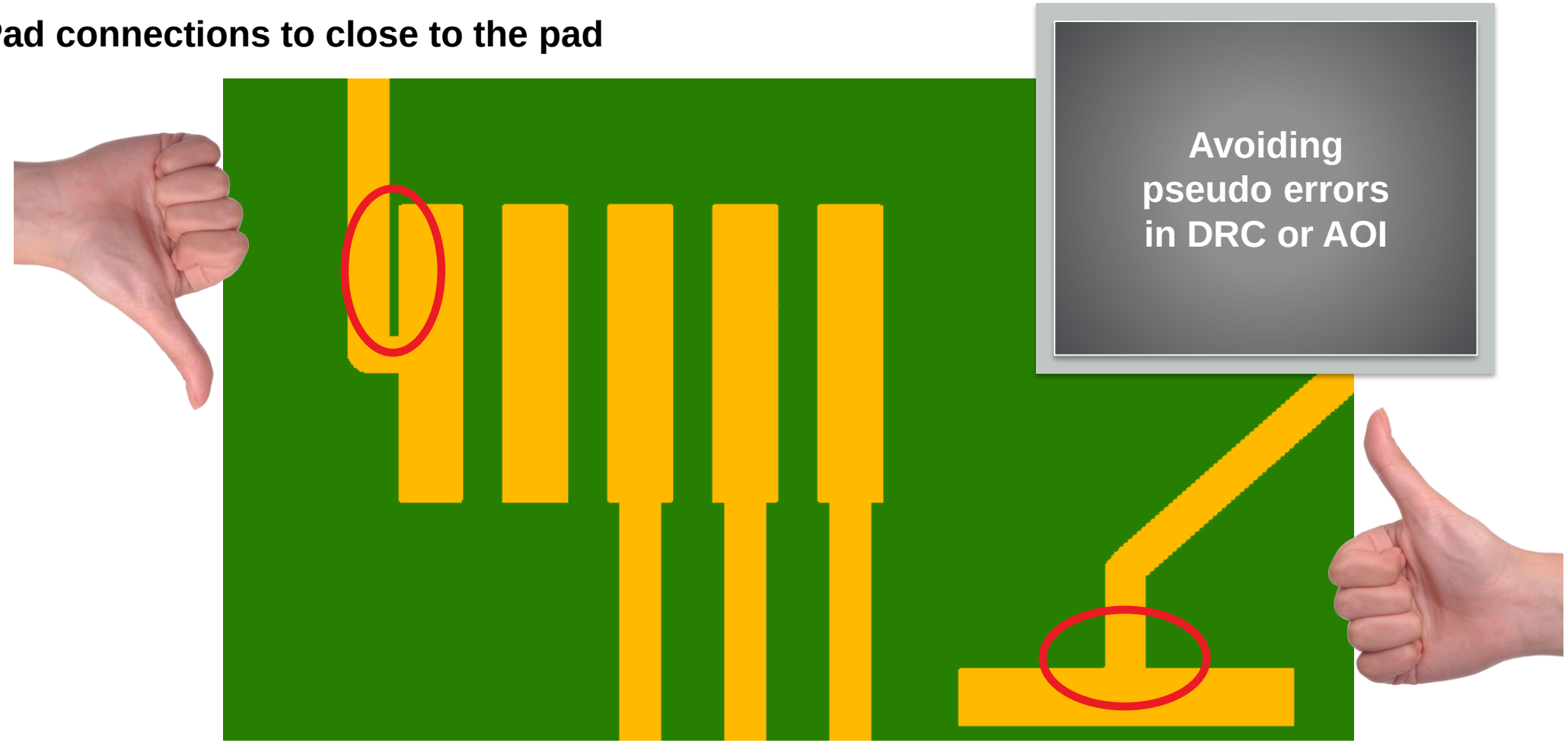
More tips & tricks

Summary

More tips & tricks

Error prevention

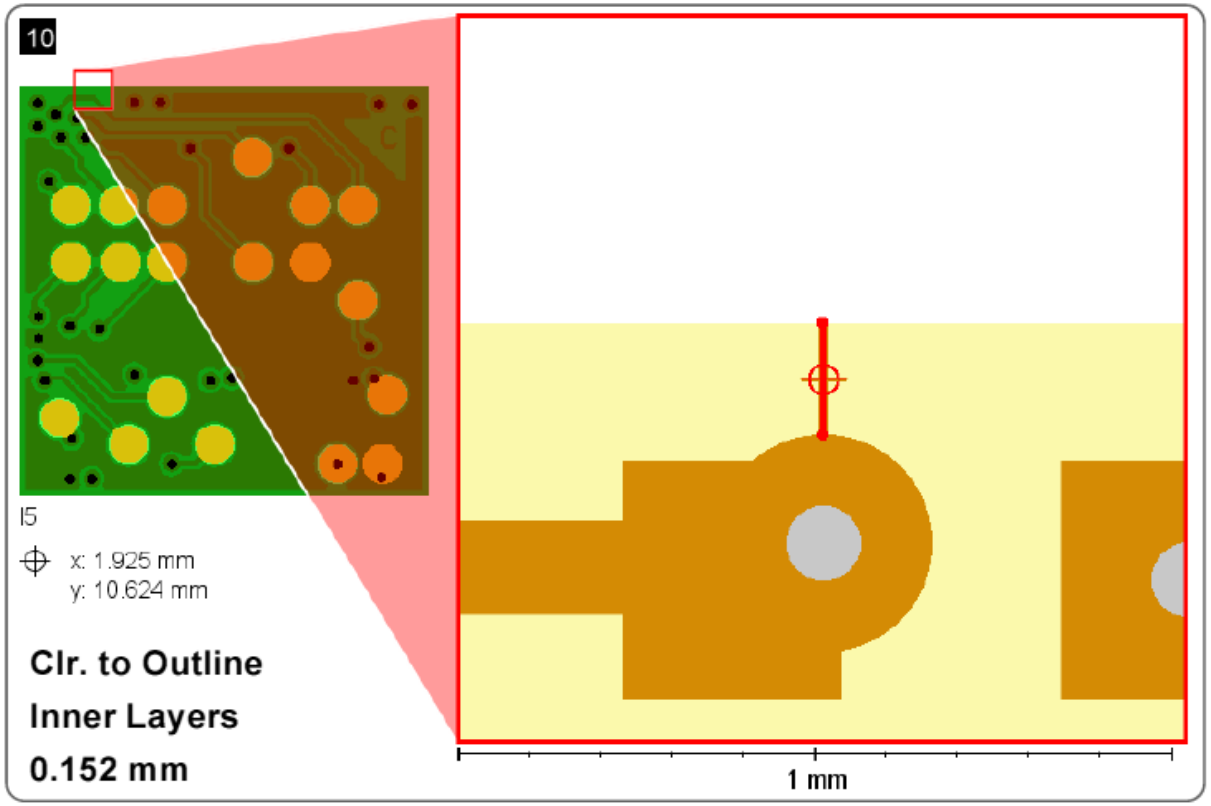
- **Pad connections to close to the pad**



More tips & tricks

Error prevention

- **Clearance to outline of planes, lines and holes incl. pads**



More tips & tricks

Data output – Gerber-Format

RS-274-D Standard Gerber

⇨ obsolete, replaced by

RS-274X Extended Gerber

Parameters for output:

- **Often preset parameters are inaccurate in modern layouts:**
  - 2.3 Inches ⇨ min. resolution 25,4 µm
  - Better: 2.5 Inches (min. resolution 0,254 µm) or
    4.4 metric (min. resolution 0,1 µm)
- **No mixing of parameters:**
  Drill data and Gerber data should be based on the same parameters due to tolerance chains in conversion of the data (especially for HDI boards)

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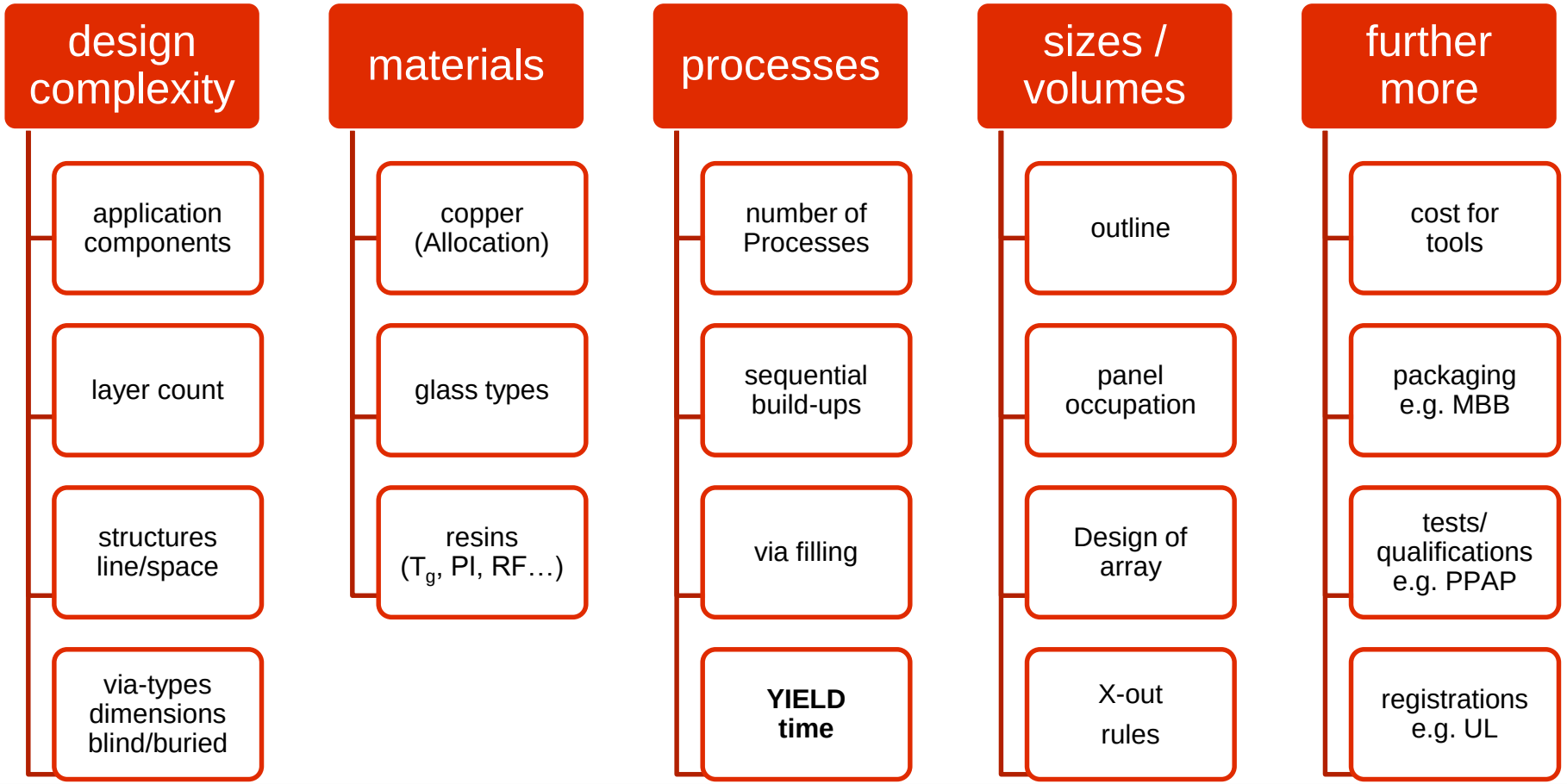
Summary

How does your PCB layout influence the costs in PCB manufacturing

- **Things to consider when manufacturing PCBs:**



Thank you very much for your attention!

WÜRTH ELEKTRONIK

What kind of Application do you have?

How can WE support You ?

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